Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.1 Summarize the overall process by which photosynthesis converts solar energy into chemical energy and interpret the chemical equation for the process.
Taxonomy Level: 2.4-B and 2.1-B Understand Conceptual Knowledge

Key Concepts:
Photosynthesis: light-dependent reactions, dark (light-independent) reactions

Previous knowledge: In 6th grade (6-2.7), students summarized the processes required for plant survival (including photosynthesis, respiration, and transpiration). In 7th grade, students explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism (7-2.4) and explained how a balanced chemical equation supports the law of conservation of matter (7-5.8).

It is essential for students to understand that all organisms need a constant source of energy to survive. The ultimate source of energy for most life on Earth is the Sun. *Photosynthesis* is the overall process by which sunlight (solar energy) chemically converts water and carbon dioxide into chemical energy stored in simple sugars (glucose). This process occurs in two stages.

- The first stage is called the *light-dependent reactions* because they require solar energy.
  - o During the light-dependent reactions, solar energy is absorbed by chloroplasts (see B-2.2) and two energy storing molecules (ATP and NADPH) are produced.
  - o The solar energy is used to split water molecules which results in the release of oxygen as a waste product, an essential step in the process of photosynthesis.
- The second stage is called the *dark (light-independent) reactions* because they do not require solar energy.
  - o During the dark (light-independent) reactions, energy stored in ATP and NADPH is used to produce simple sugars (such as glucose) from carbon dioxide. These simple sugars are used to store chemical energy for use by the cells at later times.
  - o Glucose can be used as an energy source through the process of cellular respiration or it can be converted to organic molecules (such as proteins, carbohydrates, fats/lipids, or cellulose) by various biologic processes.

TEACHER NOTE: The structure of ATP molecules and a deeper treatment of its function are addressed in B-3.3.

It is also essential for students to understand that the process photosynthesis is generally represented using a balanced chemical equation. However, this equation does not represent all of the steps that occur during the process of photosynthesis.

$$6CO_2 + 6H_2O \xrightarrow{\text{Solar energy}} C_6H_{12}O_6 + 6O_2$$

- In general, six carbon dioxide molecules and six water molecules are needed to produce one glucose molecule and six oxygen molecules.
- Each of the reactants (carbon dioxide and water) is broken down at different stages of the process.
- Each of the products (oxygen and glucose) is formed in different stages of the process.
- Solar energy is needed to break down the water molecules.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

It is not essential for students to understand

- the chemical processes of the Calvin cycle (carbon fixation);
- how the structure of chloroplast is important to the process of photosynthesis (the thylakoid and stroma).

Assessment Guidelines:

The first objective of this indicator is to *summarize* the process by which photosynthesis converts solar energy into chemical energy; therefore, the primary focus of assessment should be to give major points about the process of photosynthesis, including light-dependent and light-independent/dark reactions.

The second objective of this indicator is to *interpret* the chemical equation for photosynthesis; therefore, the primary focus of assessment should be to represent the process of photosynthesis through the use of a chemical equation and its chemical symbols.

In addition to *summarize* and *interpret*, assessments may require students to

- *recognize* the formulas for the components of the overall equation for photosynthesis;
- *recognize* ATP, NADPH, and glucose as chemical compounds that store energy in their bonds;
- *compare* the energy transformations that occur in the dark reactions to those that occur in the light reactions.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.2 Summarize the basic aerobic and anaerobic processes of cellular respiration and interpret the chemical equation for cellular respiration.
Taxonomy Level: 2.4-B and 2.1-B Understand Conceptual Knowledge

Key Concepts:
Cellular respiration: adenosine triphosphate (ATP)
Glycolysis
Aerobic respiration: Krebs cycle (citric acid cycle), electron transport chain
Anaerobic respiration: fermentation, lactic acid fermentation, alcohol fermentation

Previous knowledge: In 6th grade (6-2.7), students summarized the processes required for plant survival (including photosynthesis, respiration, and transpiration). In 7th grade, students explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism (7-2.4) and explained how a balanced chemical equation supports the law of conservation of matter (7-5.8).

It is essential for students to understand that the ultimate goal of *cellular respiration* is to convert the chemical energy in nutrients to chemical energy stored in *adenosine triphosphate (ATP).* ATP can then release the energy for cellular metabolic processes, such as active transport across cell membranes, protein synthesis, and muscle contraction.

- Any food (organic) molecule, or nutrient, including carbohydrates, fats/lipids, and proteins can be processed and broken down as a source of energy to produce ATP molecules.

$$\text{nutrients} + \text{oxygen} \longrightarrow \text{water} + \text{energy (ATP)} + \text{carbon dioxide}$$

TEACHER NOTE: The structure of ATP molecules and a deeper treatment of its function are addressed in B-3.3.

To transfer the energy stored in glucose to the ATP molecule, a cell must break down glucose slowly and capture the energy in stages.

- The first stage is *glycolysis*.
  - In the process of glycolysis a glucose molecule is broken down into pyruvic acid molecules and ATP molecules.
  - Glycolysis is a series of reactions using enzymes that takes place in the cytoplasm.

TEACHER NOTE: Pyruvic acid is a pyruvate molecule that has combined with a hydrogen ion. Many texts use the terms interchangeably.

- If oxygen is available, the next stage is the two-step process of *aerobic respiration*, which takes place primarily in the mitochondria of the cell.
  - The first step of aerobic respiration is called the *citric acid* or *Krebs cycle.*
    - ♦ The pyruvic acid formed in glycolysis travels to the mitochondria where it is chemically transformed in a series of steps, releasing carbon dioxide, water, and energy (which is used to form 2 ATP molecules)

$$\text{Pyruvic acid} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy (2 ATP)}$$

  - The second step of aerobic respiration is the *electron transport chain*.
    - ♦ Most of the energy storing ATP molecules is formed during this part of the cycle.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

- ♦ The electron transport chain is a series of chemical reactions ending with hydrogen combining with oxygen to form water. Carbon dioxide is released as a waste product as it is formed in several stages of the Krebs cycle.
- ♦ Each reaction produces a small amount of energy, which by the end of the cycle produces many (up to 36) ATP molecules.
- ♦ The ATP synthesized can be used by the cell for cellular metabolism

It is also essential for students to understand that the process aerobic respiration is generally represented using a balanced chemical equation. However, this equation does not represent all of the steps that occur during the process of aerobic respiration.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

- In general, one glucose molecule and six oxygen molecules are needed to produce six carbon dioxide molecules and six water molecules.
- Each of the reactants (glucose and oxygen) is used during different stages of aerobic respiration.
- Each of the products (carbon dioxide and water) is formed during different stages of the process.
- The energy that is released is primarily used to produce approximately 34 to 36 molecules of ATP per glucose molecule.

It is essential for students to understand that if no oxygen is available, cells can obtain energy through the process of *anaerobic respiration.* A common anaerobic process is *fermentation*.

- Fermentation is not an efficient process and results in the formation of far fewer ATP molecules than aerobic respiration.
- There are two primary fermentation processes:
  - ○ *Lactic acid fermentation* occurs when oxygen is not available, for example, in muscle tissues during rapid and vigorous exercise when muscle cells may be depleted of oxygen.
    - ♦ The pyruvic acid formed during glycolysis is broken down to lactic acid, and in the process energy is released (which is used to form ATP).

Glucose → Pyruvic acid → Lactic acid + energy

    - ♦ The process of lactic acid fermentation replaces the process of aerobic respiration so that the cell can continue to have a continual source of energy even in the absence of oxygen, however this shift is only temporary and cells need oxygen for sustained activity.
    - ♦ Lactic acid that builds up in the tissue causes a burning, painful sensation.

TEACHER NOTE: Lactic acid is lactate which has acquired a hydrogen ion. Many texts use the two interchangeably.

  - ○ *Alcohol fermentation* occurs in yeasts and some bacteria.
    - ♦ In this process, pyruvic acid formed during glycolysis is broken down to produce alcohol and carbon dioxide, and in the process energy is released (which is used to form ATP).

Glucose → Pyruvic acid → alcohol + carbon dioxide + energy

TEACHER NOTE: At this point teachers may want to compare the processes of photosynthesis and aerobic respiration.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

It is not essential for students to understand

- the specific chemical reactions of cellular respiration;
- the role of excited electrons or the mechanism of the electron transport system in the process of respiration;
- the role of NADH in respiration or fermentation.

Assessment Guidelines:

The first objective of this indicator is to *summarize* the basic aerobic and anaerobic processes of cellular respiration; therefore, the primary focus of assessment should be to give major points about the process of cellular respiration, both aerobic and anaerobic.

The second objective of this indicator is to interpret the chemical equation for cellular respiration; therefore, the primary focus of assessment should be to represent the process of aerobic respiration through the use of a chemical equation and its chemical symbols.

In addition to summarize and interpret, assessments may require students to

- *recognize* the formulas for the components of the overall equation for cellular respiration;
- *recognize* glucose and ATP as chemical compounds that store energy in their bonds;
- *explain* why cellular respiration is critical to an organism;
- *compare* aerobic and anaerobic respiration as processes that produce energy.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.3 Recognize the overall structure of adenosine triphosphate (ATP)—namely, adenine, the sugar ribose, and three phosphate groups—and summarize its function (including the ATP-ADP [adenosine diphosphate] cycle).

Taxonomy Level: 1.1-A Remember Factual knowledge
2.4-B Understand Conceptual Knowledge

Key Concepts:
ATP structure: nitrogenous base (adenine), ribose, phosphate group
ATP-ADP cycle

Previous knowledge: This concept has not been addressed in previous grades.

It is essential for students to remember that *adenosine triphosphate (ATP)* is the most important biological molecule that supplies energy to the cell. A molecule of ATP is composed of three parts:

- A *nitrogenous base (adenine)*
- A sugar *(ribose)*
- Three *phosphate groups* (therefore the name triphosphate) bonded together by "high energy" bonds

It is also essential for students to understand the *ATP-ADP cycle*.

- Cells break phosphate bonds as needed to supply energy for most cellular functions, leaving adenosine diphosphate (ADP) and a phosphate available for reuse.
  - When any of the phosphate bonds are broken or formed, energy is involved.
    - Energy is released each time a phosphate is removed from the molecule.
    - Energy is used each time a phosphate attaches to the molecule.
  - To constantly supply the cell with energy, the ADP is recycled creating more ATP which carries much more energy than ADP.
- The steps in the ATP-ADP cycle are
  - To supply cells with energy, a "high energy" bond in ATP is broken. ADP is formed and a phosphate is released back into the cytoplasm.

    $$\text{ATP} \rightarrow \text{ADP} + \text{phosphate} + \text{energy}$$

  - As the cell requires more energy, ADP becomes ATP when a free phosphate attaches to the ADP molecule. The energy required to attach the phosphate to ADP is much less than the energy produced when the phosphate bond is broken.

    $$\text{ADP} + \text{phosphate} + \text{energy} \rightarrow \text{ATP}$$

It is not essential for students to remember

- the chemical formula for ATP or ADP;
- the starting molecule (AMP) or the ADP-AMP cycle.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

Assessment Guidelines:
The first objective of this indicator is to *recognize* the overall structure of the ATP molecule; therefore, the primary focus of assessment should be to remember the three main parts of ATP (adenine, ribose, and three phosphate groups).

The second objective of this indicator is to *summarize* the function of ATP; therefore the primary focus of assessment should be to give major points about the function of an ATP molecule as a source of stored chemical energy for the cell, including the ATP-ADP cycle. Assessments should ensure that students understand the relevance of the process of breaking the high energy bonds in order to provide energy for cellular functions and how the ATP gets recycled through the ATP-ADP cycle.

In addition to *recognize* and *summarize*, assessments may require students to
- *identify* the components of ATP from diagrams;
- *interpret* diagrams and equations of the ATP-ADP cycle.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.4 Summarize how the structures of organic molecules (including proteins, carbohydrates, and fats) are related to their relative caloric values.
Taxonomy Level: 2.4-B Understand Conceptual Knowledge

Key Concepts:
Organic molecules (as listed in the indicator)
Caloric value
Protein: amino acid
Carbohydrates: monosaccharides
Fats (lipids): glycerol, fatty acids

Previous knowledge: This concept has not been addressed in previous grades.

It is essential for students to understand that all organisms are composed of *organic molecules* which contain carbon atoms. Most organic molecules are made of smaller units that bond to form larger molecules. Energy is stored in the bonds that link these units together. The amount of energy stored in these bonds varies with the type of molecule formed. As a result, not all organic molecules have the same amount of energy available for use by the organism. The energy stored in organic molecules determines its *caloric value*. Proteins, carbohydrates, and fats/lipids are three organic molecules with different structures and different caloric values based on those structures.

- *Proteins* are molecules composed of chains of *amino acids.*
  - Amino acids are molecules that are composed of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.
  - There are 20 amino acids that chemically bond in various ways to make proteins. Twelve of these amino acids are made in the body; others must be consumed from foods such as nuts, beans, or meat.
  - Although proteins are more important as a source of building blocks, amino acids may be used by the body as a source of energy (through the process of cellular respiration), but first they must be converted by the body to carbohydrates. This process does not happen as long as there is a carbohydrate or lipid available.
  - As a source of energy, proteins have the same caloric value per gram as carbohydrates.
- *Carbohydrates* (sugars and starches) are molecules composed of carbon, hydrogen, and oxygen.
  - The basic carbohydrates are simple sugars (*monosaccharides*) such as glucose. These simple sugars can bond together to make larger, complex carbohydrate molecules, for example starch or cellulose.
  - Carbohydrates are important because they the main source of energy for the cell.
    - ♦ When carbohydrates are synthesized during the process of photosynthesis, the plants or other photosynthetic organisms use them as a source of energy or they are stored in the cells.
    - ♦ When complex carbohydrates are consumed, the process of digestion breaks the bonds between the larger carbohydrate molecules so that individual simple sugars can be absorbed into the bloodstream through the walls of the intestines.
      - * The bloodstream carries the simple sugars to cells throughout the body where they cross into the cells through the cell membrane.
      - * Once inside the cells, simple sugars are used as fuel in the process of cellular respiration, releasing energy which is stored as ATP.

- ○ The caloric value of carbohydrates is dependent on the number of carbon-hydrogen bonds. If an organism has a greater supply of carbohydrates than needed for its energy requirements, the extra energy is converted to fats and stored by the body.
- *Lipids,* including *fats,* are organic molecules composed of carbon, hydrogen, and oxygen.
  - ○ Lipid molecules are made of two component molecules (*glycerols* and *fatty acids*) so they are structurally different from carbohydrates. Fats/lipids have more carbon-hydrogen bonds than carbohydrates.
  - ○ Fats are important to organisms for energy when carbohydrates are scarce, but when there is no shortage of food, stored fat accumulates.
    - ♦ When fats are consumed, the molecules are broken down during the process of digestion so that individual glycerol and fatty acid molecules are absorbed into the bloodstream through the walls of the intestines.
    - ♦ The blood stream carries the glycerol and fatty acid molecules to cells throughout the body where the molecules cross into the cells through the cell membrane.
    - ♦ Once inside the cell, glycerols and fatty acids are stored for later use or used as fuel for cellular respiration if there are no carbohydrates available.
    - ♦ The process of cellular respiration releases the energy that is held in the chemical bonds of the glycerol and fatty acid molecules.
- Due to the structure and number of the carbon-hydrogen bonds that hold the different types of molecules (proteins, carbohydrates, or fats) together, fats contain more energy (ATP) per gram than carbohydrates or proteins, which explains why fats have a greater caloric value.

It is not essential for students to understand
- the structures of carbon molecules;
- the chemical formulas for proteins, carbohydrates, or fats;
- the bonding in proteins, carbohydrates, or fats (peptide bonds or the process of hydrolysis);
- the energy value of the molecules mole per mole;
- the mathematical calculations concerning energy values per gram of substance.

Assessment Guidelines:
The objective of this indicator is to *summarize* how the structures of organic molecules (including proteins, carbohydrates, and fats) are related to their relative caloric values; therefore, the primary focus of assessment should be to give major points about the overall structure of the three types of molecules and how the structures determine the amount of energy available.

In addition to *summarize*, assessments may require students to
- *recall* the basic components of each type of organic molecule;
- *compare* the structure and relative caloric value of proteins, carbohydrates, and fats.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.5 Summarize the functions of proteins, carbohydrates, and fats in the human body.
Taxonomy Level: 2.4-B Understand Conceptual Knowledge

Key Concepts:
Proteins Carbohydrates Fats

Previous knowledge: This concept has not been addressed in previous grades.

It is essential for students to understand that proteins, carbohydrates, and fats have important functions within the human body.

- *Proteins* are involved in almost every function in the human body. For example, they serve as the basis for structures, transport substances, regulate processes, speed up chemical reactions, and control growth.
  - Proteins are more important as a source of building blocks than as a source of energy. Proteins can function as an energy source only if there is a shortage of carbohydrates or lipids.
    - When proteins are consumed, the bonds that hold the amino acids together are broken during the process of digestion so that individual amino acids are absorbed into the bloodstream through the walls of the intestines.
    - The amino acids are carried by the blood stream to cells throughout the body where they cross into the cells through the cell membrane.
    - Once inside the cell, they are used as raw materials to make all of the proteins required by the organism.
  - Because of their structures, proteins serve different functions. For example,
    - Structural proteins are used for support such as connective tissue and keratin that forms hair and finger nails.
    - Transport proteins transport many substances throughout the body such as hemoglobin which transports oxygen from the lungs to the other parts of the body to be used by cells in cellular respiration.
    - Hormone proteins coordinate body activities such as insulin which regulates the amount of sugar in the blood.
    - Contractile proteins help control movement such as proteins in the muscles which help control contraction.
    - Enzymatic proteins accelerate the speed of chemical reactions such as digestive enzymes which break down food in the digestive tract.
- *Carbohydrates* are important as an energy source for all organisms and as a structural molecule in many organisms.
  - Carbohydrates are a primary source of fuel for cellular respiration.
  - Carbohydrates are also used to store energy for short periods of time.
  - The carbon, hydrogen, and oxygen that compose carbohydrates serve as raw materials for the synthesis of other types of small organic molecules, such as amino acids and fatty acids.
  - Some carbohydrates (such as cellulose) are used as structural material in plants.
    - For most animals, foods that contain these carbohydrates are important as fiber which stimulates the digestive system.
- *Fats (lipids)* are important to organisms for energy when carbohydrates are scarce since they are the primary way to store energy.
  - Fats serve a variety of functions in humans, such as providing long-term energy storage, cushioning of vital organs, and insulation for the body.

- ○ Fats also serve as a major component of cell membranes and are one of the raw materials necessary for the production of some vitamins and hormones.

Assessment Guidelines:
The objective of this indicator is to *summarize* the functions of proteins, carbohydrates, and fats in the human body; therefore, the primary focus of assessment should be to give major points about the importance of proteins, carbohydrates, and fats to health of human beings.

In addition to *summarize*, assessments may require students to
- *recall* or *compare* the functions of each organic molecule.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

B-3.6 Illustrate the flow of energy through ecosystems (including food chains, food webs, energy pyramids, number pyramids, and biomass pyramids).
Taxonomy Level: 2.2-B Understand Conceptual Knowledge

Key Concepts:
Food chain, food web
Trophic level: primary producers (autotrophs), primary consumers (heterotrophs)
Types of consumers: herbivore, carnivore, omnivore, detritivore
Ecological pyramids: energy pyramid, number pyramid, biomass pyramid

Previous knowledge: In 5th grade (5-2.4), students identified the roles of organisms as they interact and depend on one another through food chains and food webs in an ecosystem, considering producers and consumers (herbivores, carnivores, omnivores), decomposers (microorganisms, termites, worms, and fungi), predators and prey, and parasites and hosts. In 7th grade (7-4.2), students illustrated energy flow in food chains, food webs, and energy pyramids.

It is essential for students to understand that the flow of energy through ecosystems can be described and illustrated in food chains, food webs, and pyramids (energy, number, and biomass).

Food Chain
A *food chain* is the simplest path that energy takes through an ecosystem. Energy enters an ecosystem from the Sun. Each level in the transfer of energy through an ecosystem is called a *trophic level*. The organisms in each trophic level use some of the energy in the process of cellular respiration, lose energy due to heat loss, and store the rest.

- The first trophic level consists of *primary producers* (green plants or other *autotrophs*).
  - Primary producers capture the Sun's energy during photosynthesis, and it is converted to chemical energy in the form of simple sugars.
  - The autotroph uses some of the simple sugars for energy and some of the simple sugars are converted to organic compounds (carbohydrates, proteins, and fats) as needed for the structure and functions of the organism.
  - Examples of primary producers include land plants and phytoplankton in aquatic environments.
- The second trophic level consists of *primary consumers (heterotrophs)*.
  - Primary consumers that eat green plants are called *herbivores*.
  - The herbivore uses some of the organic compounds for energy and some of the organic compounds are converted into the proteins, carbohydrates and fats that are necessary for the structure and functions of the herbivore. Much of the consumed energy is lost as heat.
  - Examples of primary consumers include grasshoppers, rabbits and zooplankton.
- The third trophic level, or any higher trophic level, consists of *consumers*.
  - Consumers that eat primary consumers are called *carnivores*; consumers that eat both producers and primary consumers are called *omnivores*.
  - The carnivores or omnivores use some of the organic compounds for energy and some of the organic compounds are converted into the proteins, carbohydrates and fats that are necessary for their body structures and functions. Much of the consumed energy is lost as heat.
  - Examples of consumers include humans, wolves, frogs, and minnows.
- A heterotroph that decomposes organic material and returns the nutrients to soil, water, and air making the nutrients available to other organisms is called a *detritivore*.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

The energy available for each trophic level in an ecosystem can be illustrated with a food chain diagram. The size of the arrow in a diagram may indicate that the energy is smaller at each trophic level because each organism uses some of the energy for life processes or lost as heat.

Food Web
A *food web* represents many interconnected food chains describing the various paths that energy takes through an ecosystem. The energy available in an ecosystem can be illustrated with a food web diagram.

Ecological Pyramids
Ecological pyramids are models that show how energy flows through ecosystems. Pyramids can show the relative amounts of energy, biomass, or numbers of organisms at each trophic level in an ecosystem. The base of the pyramid represents producers. Each step up represents a different level of consumer. The number of trophic levels in the pyramid is determined by the number of organisms in the food chain or food web.

- An *energy pyramid* represents the energy available for each trophic level in an ecosystem.
  - The energy needs of organisms are greater from level to level in an ecosystem.
  - Therefore, the total amount of energy available at each level decreases in an ecosystem.
  - Each successive level in an ecosystem can support fewer numbers of organisms than the one below. With each level of the pyramid, only 10% of the energy available is used by organisms while there is an energy loss of about 90% to the environment.
- A *number pyramid* represents the number of individual organisms available for energy at each trophic level in an ecosystem. It can be used to examine how the population of a certain species affects another.
  - The autotrophic level is represented at the base of the pyramid. This represents the total number of producers available to support the energy needs of the ecosystem.
  - The total numbers of individual organisms tend to decline as one goes up trophic levels.
- A *biomass pyramid* represents the total mass of living organic matter (biomass) at each trophic level in an ecosystem.
  - Since the number of organisms is reduced in each successive trophic level, the biomass at each trophic level is reduced as well.
  - Even though a biomass pyramid shows the total mass of organisms available at each level, it does not necessarily represent the amount of energy available at each level. For example, the skeleton and beak of a bird will contribute to the total biomass but are not available for energy.

It is not essential for students to understand
- the flow of energy in terms of the laws of thermodynamics or entropy;
- how to calculate the amount of energy available in an energy pyramid or the amount of biomass available in a biomass pyramid;
- the exact proportion of organisms that exists at each trophic level in a numbers pyramid.

Standard B-3: The student will demonstrate an understanding of the flow of energy within and between living systems.

Assessment Guidelines:
The objective of this indicator is to *illustrate* the flow of energy through ecosystems (including food chains, food webs, energy pyramids, number pyramids, and biomass pyramids); therefore, the primary focus of assessment should be to give or use illustrations of food chains, food webs, energy pyramids, numbers pyramids, and biomass pyramids for a given ecosystem showing that the organisms in each trophic level use some of the energy in the process of cellular respiration, lose energy due to heat loss, and store the rest.

In addition to *illustrate*, assessments may require students to
- *interpret* a scientific drawing of a food chain, food web, energy pyramid, numbers pyramid, or biomass pyramid;
- *summarize* the energy flow represented in a food chain, food web, energy pyramid, numbers pyramid or a biomass pyramid for a given ecosystem;
- *compare* different trophic levels in an ecosystem as to energy, numbers of organisms and biomass.